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ANALYSIS OF THE RELATIONSHIP BETWEEN TOTAL NITROGEN AND AVAILABLE NITROGEN IN NON-PASTORAL TOPSOILS OF NEW ZEALAND FROM A LARGE SOIL TEST DATABASE

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Abstract

Using a large soil test database, the relationship between total nitrogen and available nitrogen (measured as anaerobically mineralisable nitrogen) in non-pastoral topsoils (0-15 cm) of New Zealand was analysed by linear regression, grouping the data into 14 regions. For most regions, a statistically significant relationship between total N and available nitrogen exists (*P* values <0.001). Furthermore, six regions exhibited good R^2 values (range 0.48 to 0.79, *P* values <0.0001). These include the Bay of Plenty, Canterbury, Gisborne, Hawke's Bay, Wellington and the West Coast. For these regions, total nitrogen analysis can be useful to predict topsoil available nitrogen with a good degree of confidence that can serve as useful guidance in fertiliser nitrogen recommendations.

Introduction

Soil total nitrogen (N) has long been analysed in routine farm soil fertility testing, soil surveys and soil quality monitoring programmes both in New Zealand and overseas. The logic behind using total N as an index of soil N availability is that the available N pool in soils ultimately comes from organic matter through the mineralisation process. Thus, intuitively, soil total N should be well correlated with measures of soil N mineralisation. However, it has also been pointed out that soil total N may fail to correlate with available N because the percentage of organic N mineralised tends to decrease as total soil N increases (Scharenbroch and Lloyd 2004). This suggests that organic matter composition or quality is important in influencing the amount of N mineralised across different soil types. Back in the 1980s, 10 out of 50 states of the USA used total N as a guide for providing N fertiliser recommendations in crops especially maize (Meisinger 1984). In the late 1980s, Selvarajah et al. (1987) carried out an evaluation of some laboratory methods of assessing the availability of N in non-pastoral soils of New Zealand of which total N and different indices of mineralisable N were some of the variables used. In that study, a significant correlation was found between total N and anaerobically mineralisable N (AMN) (r=0.61, *P*<0.001) for 82 arable topsoil (0-15 cm) samples collected by Ravensdown Fertiliser Co-op. Similarly, a significant correlation was found for 15 South island soils (r=0.69, *P*<0.001) collected by the then Ministry of Agriculture and Fisheries. Guinto (2014) examined publicly available soil health monitoring data from selected regional councils in New Zealand and showed that total N was good predictor of AMN with R^2 values ranging from 0.68 to 0.81 (*P* values <0.001). Currently, AMN is employed as an index of available N and is used as a guide in N fertilisation but is considered more expensive and time consuming to analyse than total N. It was suggested that Ballance explore the use of the Hill Laboratories soil test database of its non-pastoral customers containing total N and AMN. This would allow Ballance to further develop the correlation between total N and available N using a larger data set and develop regression equations for these relationships. Therefore, the objective of this work is to find out if there is a significant linear relationship between total N (TOTN) and anaerobically mineralisable N (AMN) in non-pastoral soils of New Zealand by region and also to find out if TOTN can be a good predictor of AMN from this large data set.

Methods

Soil total N and AMN data were obtained from Hill Laboratories, Hamilton. The original data set provided consisted of more than 10,000 observations from soil tests coming from Ballance customers under non-pastoral land uses (maize, barley, wheat, brassicas, kiwifruit, oats, potatoes, vegetables, etc.) and different topsoil depths (0-7.5, 0-10, 0-15 cm, etc.). In many cases, description of crop types in the database was too general being reported only as arable. It should be noted that data on soil types are not included in this soil N database and therefore could not be used as a grouping or predictor variable. Soil total N was measured using near infrared spectroscopy (NIRS) [http://www.hill-laboratories.com/file/fileid/49297] while AMN was analysed using the 7-day anaerobic incubation test [http://www.hill-laboratories.com/file/fileid/45371]. Data were grouped according to regions and focused on the standard 0-15 cm depth. Summary statistics (mean, standard variation, coefficient of variation, etc. were computed). A few TOTN data were below limits of detection (<0.04%). In such cases, the numbers were replaced by substituting half the limit of detection (i.e. 0.02%), a recommended practice when dealing with only a few censored data (McBride 2005). For each region, linear regression analysis was performed. Plots of residuals and predicted AMN values were done to check on model adequacy (non-normality, variance heterogeneity, etc.). Square root transformation of both TOTN and AMN variables were performed to satisfy the assumptions of regression analysis. In a few cases, extreme observations or outliers were removed prior to regression analysis to improve the goodness of fit (Chaiterjee and Hadi 1988).

Results and Discussion

Summary statistics

Table 1 shows the summary statistics for both TOTN and AMN. Mean TOTN values ranged from 0.27% in Gisborne through to 0.79% in Taranaki. The coefficients of variation range from 15.4% in Taranaki through to 44.6% in Hawke's Bay. Mean AMN values ranged from 70 mg/kg in Gisborne through to 204 mg/kg in Northland. The coefficients of variation range from 27.9% in Southland through to 53.4% in Gisborne. With few exceptions, the coefficients of variation for AMN were higher than for TOTN. Most distributions are skewed to the right and so transformations using square roots were required to satisfy linear regression assumptions.

Table 1. Descriptive statistics of topsoil (0-15 cm) total N and anaerobically mineralisable N by region from the Hill Laboratories Ballance non-pastoral client database.

Region	**Total N**				
	Mean (%)	**SD (%)**	**Min (%)**	**Max (%)**	**CV (%)**
Auckland (n=404)	0.57	0.25	0.16	1.85	41.6
Bay of Plenty (n=372)	0.46	0.14	0.10	0.85	30.8
Canterbury (n=1988)	0.34	0.09	0.15	0.98	25.4
Gisborne (n=206)	0.27	0.11	0.02	0.76	41.5
Hawke's Bay (n=317)	0.41	0.18	0.11	0.91	44.6
Manawatu/Wanganui (n=768)	0.41	0.19	0.09	1.17	40.3
Marlborough (n=39)	0.39	0.10	0.19	0.58	24.8
Nelson (n=2)	0.49	0.18	0.37	0.62	35.7
Northland (n=699)	0.55	0.20	0.20	1.79	36.1
Otago (n=468)	0.34	0.08	0.17	0.66	23.1
Southland (n=681)	0.43	0.14	0.16	1.27	31.4
Taranaki (n=250)	0.79	0.12	0.41	1.07	15.4
Tasman (n=6)	0.40	0.11	0.24	0.56	27.3
Waikato (n=2988)	0.67	0.29	0.11	2.03	43.6
Wellington (n=188)	0.36	0.10	0.18	0.73	27.1
West Coast (n=337)	0.42	0.18	0.02	0.84	43.1
	Anaerobically mineralisable N (AMN)				
Region	**Mean (mg/kg)**	**SD (mg/kg)**	**Min (mg/kg)**	**Max (mg/kg)**	**CV (%)**
Auckland (n=404)	162	67	16	367	44.0
Bay of Plenty (n=372)	109	45	15	300	41.4
Canterbury (n=1988)	114	43	22	287	37.5
Gisborne (n=206)	70	37	11	242	53.4
Hawke's Bay (n=317)	102	50	22	287	48.9
Manawatu/Wanganui (n=768)	128	52	26	279	45.5
Marlborough (n=39)	131	46	54	220	35.4
Nelson (n=2)	177	67	130	225	37.7
Northland (n=699)	204	60	17	525	29.3
Otago (n=468)	145	47	30	269	32.2
Southland (n=681)	172	48	39	330	27.9
Taranaki (n=250)	137	43	52	254	31.4
Tasman (n=6)	172	52	73	215	30.4
Waikato (n=2988)	148	62	17	574	41.8
Wellington (n=188)	121	41	38	280	33.7
West Coast (n=337)	133	65	9	327	49.2

n = number of samples; SD = sample standard deviation; Min = minimum; Max = maximum; CV = coefficient of variation

Regressions on untransformed data

With the exception of Nelson (n=2) and Tasman (n=6) regions that have very small sample sizes, all regression results for untransformed data are significant at the 1% level or better for the rest of the regions (data not shown). This confirms that a linear relationship exists between TOTN and AMN. However, R^2 values were variable ranging from 0.04 to 0.74 so prediction of AMN from TOTN for regions with low R^2 is not possible. As an example, for the Waikato region, R^2 value was not high (0.31) considering there were almost 3,000 data points used. The diversity of soil types and the large area of the Waikato region is probably an important factor that needs to be considered in arriving at an improved regression relationship. Unfortunately, soil types or soil classification data were not recorded in the database. Regions where R^2 values were high (0.48 or more) include Bay of Plenty, Canterbury, Gisborne, Hawke's Bay, Wellington and the West Coast.

Regressions on transformed data

Figure 1 shows selected linear regression relationships for six regions with high coefficients of determination (R^2 values). In general, square root transformation has improved the R^2 values and distribution of the residuals of the original regression equations for most of the regions (Data for other regions not shown). The success of the square root transformation lies in the fact that within each region, variances for TOTN and AMN are greater than their respective means. Given the inherent variability of AMN measurements and considering the large sample sizes in regions where R^2 values are about 0.48 or more, these equations can be used to predict AMN from TOTN data with some degree of confidence. This situation is particularly true for Bay of Plenty, Canterbury, Gisborne, Hawke's Bay, Wellington and the West Coast.

Conclusion and Recommendations

For most regions, a statistically significant relationship between TOTN and AMN exists. Square root transformation appears sufficient to use for improving goodness of fit of the regression equations for most regions. In regions where R^2 values are 0.48 or better, regression equations with square root transformation can be used to predict AMN based on TOTN data.

In the future, further collection of these data is suggested to improve the existing regression equations. When refined, TOTN data can be used as an estimate of available N in non-pastoral soils with a greater degree of confidence.

Ballance should consider running some experiments similar to what was done for its N fertiliser application decision support tool for pastures (Shepherd et al. 2015). A scoping exercise is essential to prioritise which crop commodities should Ballance focus on.

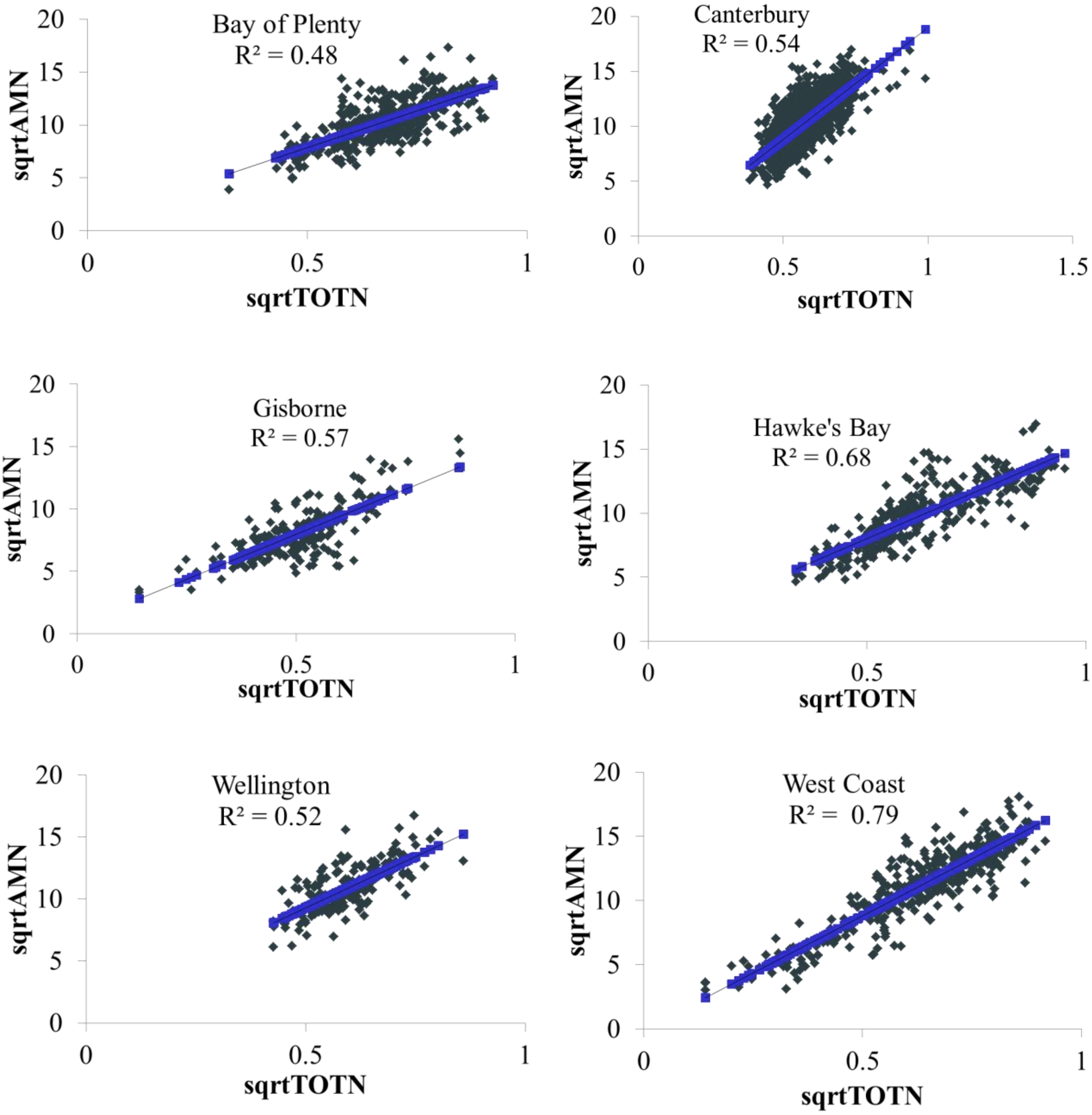

Figure 1. Relationship between total N and AMN in non-pastoral topsoils (0-15 cm) of selected regions in New Zealand with R^2 values ≥0.48 (*P*<0.0001).

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